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Dynamics and evolution of complex food web networks

The importance of evolution to ecological dynamics is increasingly being recognized, as more evidence points to smaller differences in time scale than previously thought. Community dynamics and evolutionary processes appear to be especially important determinants of ecosystem response to environmental change. Recent studies of ecological networks have advanced our understanding of how evolutionary processes and ecological interactions such as omnivory, competition, and mutualism affect ecological structure and stability. These and other advances such as those in understanding the role of biodiversity in ecosystem function have motivated the development of community evolution models such as ours that helps understand ecological change and unify ecological theory by integrating community and ecosystem ecology with evolutionary biology.

Our model begins with relatively small food web networks (20 species or less) and evolves larger networks through a process of stochastic speciation and deterministic population dynamics. It is based on an allometric trophic network model that specifies food-web structure using a stochastic model of network architecture and community dynamics comprised of a set of ordinary differential equations that govern the change in species biomass over time. Speciation proceeds by introducing new species at low population densities with traits slightly different from randomly chosen parent species. Traits include body size, trophic generality, and diet based on location and feeding ranges within the one-dimensional community niche space. Network and species properties such as diversity and biomasses are subsequently tracked through time.

The resulting evolved ecosystem networks are highly diverse and exhibit realistic properties. They share many properties including network structure and body-size-abundance distributions with their empirical counterparts. Other networks are relatively short and fat (many species at few levels) or tall and thin (few species at many trophic levels). Including shared nutrient limitation among basal species increases the likelihood of obtaining more reasonable distributions of diversity among trophic levels. Connectance varies during community evolution. The generality, vulnerability and niche overlap of species and their neighbors within the network help determine which species persist and which go extinct. Whole-network properties of the food webs evolve in response to speciation as webs increase in complexity. This work shows how a few and relatively simple evolutionary and ecological assumptions and models can be integrated to help understand ecological change while yielding complex and realistic ecosystem structures through time.